Effects of Shared Lane Markings on Bicyclist and Motorist Behavior along Multi-Lane Facilities

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Executive Summary

Census data and research surveys have shown that the number of trips made by bicycle in Austin is increasing. While Austin has a sizeable network of bicycle lanes, many gaps remain where roadways are too narrow to accommodate separated facilities. It is a considerable challenge to retrofit existing roadways to accommodate bicycles, so a need exists for planning and engineering tools that allow for motorists and bicyclists to share roadways safely. One potential tool to meet this need is the Shared Lane Marking. This roadway marking, also known as a "sharrow," is placed in the position within the roadway lane that is deemed to be the safest position for bicyclists with the goals of encouraging bicyclists to ride along the sharrow, and to alert motorists to expect bicyclists at this position. This marking is included in the newly released 2009 Manual of Uniform Traffic Control Devices (MUTCD). At the time the research in this report began, the 2009 MUTCD had not been released so a request for experimentation was approved by the Federal Highway Administration.

The primary goal of this study was to determine what effect, if any, sharrows have on bicyclist and motorist safety. Therefore, pre- and post-implementation data for each site were compared to determine if the markings improved safety. First, safe bicyclist behavior was defined by three factors: (1) riding in the lane position indicated by the sharrow, (2) not riding outside of the lane (on the sidewalk or in empty parking spaces), and (3) not riding alongside queues of stopped vehicles. Second, safe motorist behavior was defined by three factors: (1) motorists give adequate space to bicyclists when passing, (2) motorists did not encroach on adjacent lanes when passing, and (3) motorists make complete lane changes when passing. To test for a change in behavior, sharrows were installed along 51st Street (between Airport Boulevard and IH-35), along Guadalupe Street (between Cesar Chavez Street and Martin Luther King Boulevard), and Dean Keeton Street (in various locations), and video footage was recorded before and after marking installation. Along Dean Keeton Street, the sharrows were placed to the right of center in the lane, since the lane is wide enough to allow motorists and bicyclists to operate side-by-side. At the other sites, the sharrows were placed in the center of the lane.

When sharrows were placed in the center of the lane, a significant change occurred in average bicyclist lateral position, away from the curb and towards the center of the lane. This result was significant both when bicyclists were being passed by motor vehicles and when no passing was occurring, but was more pronounced in the latter instance. On Dean Keeton Street, average bicyclist lateral position during passing events did not change significantly, but the standard deviation decreased substantially after the installation of the marking. This resulted in more predictable bicyclist behavior as bicyclists tended to follow the path of sharrows. Additionally, improvement in motorist behavior during passing events was also observed. At several sites, motorists were more likely to change lanes when passing and less likely to encroach on the adjacent lane during passing events. This suggests that motorists were made more aware of bicyclists by the presence of the Shared Lane Marking. Generally, fewer bicyclists rode on sidewalks or in empty parking stalls after sharrows were installed. However, at sites where bicyclists were approaching the intersection, the number of bicyclists riding around a queue of vehicles to get to the front of the line remained unchanged or increased after the installation of sharrows. These mixed results show that Shared Lane Markings may not always be effective at reducing unsafe bicyclist maneuvers. While none of the results can individually quantify safety, the collective observations in this study strongly suggest that Shared Lane Markings, when used as either a stand alone device or as a tool to connect facilities with bicycle lanes, improve safety on multi-lane roadways that are too narrow to accommodate bicycle lanes.

Background

Over 20 the last 20 years, the City of Austin has seen a significant growth in bicycle facilities. Douma and Cleaveland (2008) documented a statistically significant increase in bicycle mode share in Austin from 1990 (0.87%) to 2000 (1.19%) in Census block groups with new bicycle routes developed during that period. During that time period, the journey-to-work bicycle mode share for Austin increased significantly from 0.76% to 0.95%. The University of Texas at Austin is the most-frequented destination in Austin with approximately 68,000 students, faculty and staff members. The university estimates 5-7% of all trips to campus are made by bicycle (BMA, 2007).

While the proportion of commuting trips made by bicycle appears to be increasing, it remains small. Surveys studying the factors affecting bicycling demand show safety to be a major concern. In a survey of bicyclists in Texas, 69% of respondents stated they feel bicycling is “somewhat dangerous” or “very dangerous” from the standpoint of traffic crashes (Sener et al., 2009). Unfortunately many roadways were not designed to be wide enough to accommodate bicyclists in a separate lane, so bicycle lanes are often disconnected at points where the roadway narrows. The experiment described here was undertaken to study the effectiveness of Shared Lane Markings to guide bicyclists and motor vehicle drivers to the correct lateral positions on the roadway and to improve motorist and bicyclist behavior in such locations.

The Manual on Uniform Traffic Control Devices (MUTCD) recommends that bike-and-chevron Shared Lane Markings be used to guide bicyclists to a safe position when the traffic lane is too narrow to be shared, alert motorists to the existence of bicyclists, encourage safe passing of bicyclists by motorists, and reduce the incidence of wrong-way bicycling. The standards and guidance developed for this marking, which are included in the 2009 MUTCD, ensure that the center of the markings is at least 11 feet from the curb face (or edge of pavement if no curb exists) when on-street parking is present. Shared Lane Markings should not be used on shoulders or bicycle lanes. The MUTCD further recommends Shared Lane Markings be reserved for roadways with a speed limit no greater than 35 mph and placed immediately after an intersection and spaced 250 feet apart or less.

A study similar to the one presented in this report found Shared Lane Markings in Gainesville, Florida led to a significant increase in bicyclists riding in the street with traffic, a small but significant increase in bicycle to curb distance (three inches), and no change in bicycle to motor vehicle distance (Pein et al., 1999). San Francisco studied two Shared Lane Marking designs - bike-in-house and bike-and-chevron – finding the latter to be the most effective. The study found significant increases in bicyclist lateral position during passing and non-passing events. Also, motor vehicles increased their distance from parked vehicles by one foot during non-passing events when a marking was present. The chevron design also decreased sidewalk riding by 35% and wrong-way riding by 80%. (Alta, 2004)

Shared Lane Markings Detail

The design of the Shared Lane Marking used in this experiment is shown in Figure 1. This design was recommended by the National Committee on Uniform Traffic Control Devices' Bicycle Technical Committee and measures 3.25 feet wide by 9.25 feet tall and is unmistakably similar to the Shared Lane Marking described in the 2009 MUTCD. The Shared Lane Markings were always placed in a manner consistent with the applicable MUTCD standards and guidance. In this paper, Shared Lane Markings are referred to as sharrows—a common shortening of 'share the road arrow.'

Thermoplastic sharrows were purchased for $123 each and were installed by a crew of five City of Austin employees for $69 each. In a single day, the crew could install up to 30 markings for a total cost of $5,760.

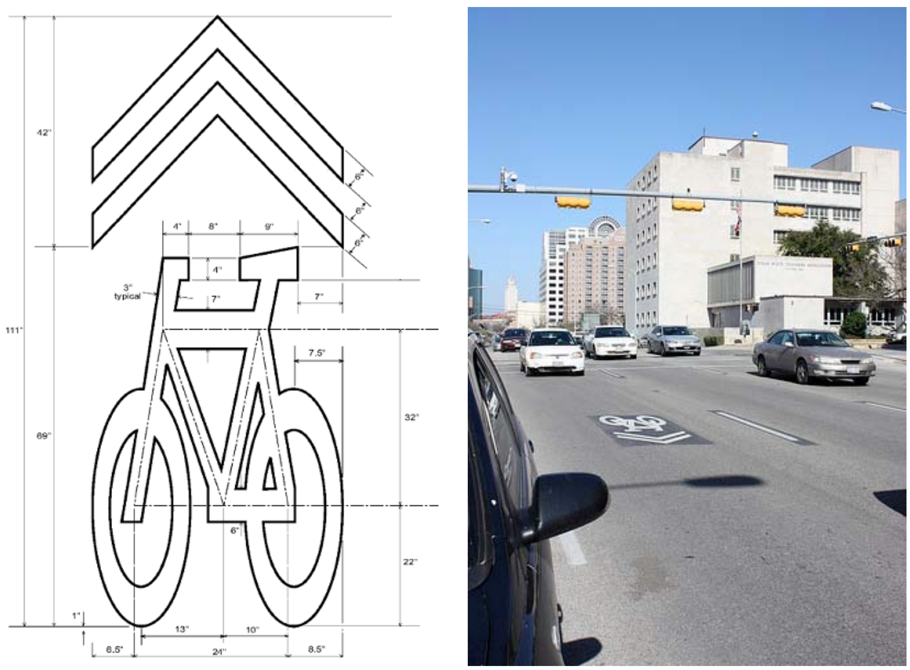

Figure 1. A drawing and photograph of the Shared Lane Marking used in this study

Site Descriptions

Shared Lane Markings were installed along three unique multi-lane facilities in Austin. Prior to the installation of the sharrows, these facilities were designated as 'low ease of use' for bicyclists by the City of Austin due to a combination of high traffic volume, narrow outside lanes, and difficult connections. At all sites, the AM peak was defined as times between 6:00 AM to 10:00 AM and the PM peak was defined between 4:00 PM and 7:00 PM.

Along Guadalupe Street between W 20th Street and W Cesar Chavez Street

Between W 20th Street and W Cesar Chavez Street, Guadalupe Street is a four lane, one-way southbound street that extends from the southern edge of campus to the southern end of downtown. Before the study began, Guadalupe was a common corridor for bicyclists despite heavy traffic and narrow outside lanes. Sharrows were installed at the beginning of each block in the center of both the rightmost and leftmost vehicle lanes—since bicycling in the leftmost lane of a one-way facility is appropriate for left-turning bicyclists. An additional pair of sharrows was placed on the north side of the intersection of Guadalupe and 12th Street to assist with data collection. A cross-section of the street is shown in Figure 2. Typical AM peak traffic volumes ranged from 800 vehicles per hour to 1100 vehicles per hour, while PM peak traffic volumes were as high as 1650 vehicles per hour. The posted speed limit on the studied section of Guadalupe Street is 30 mph.

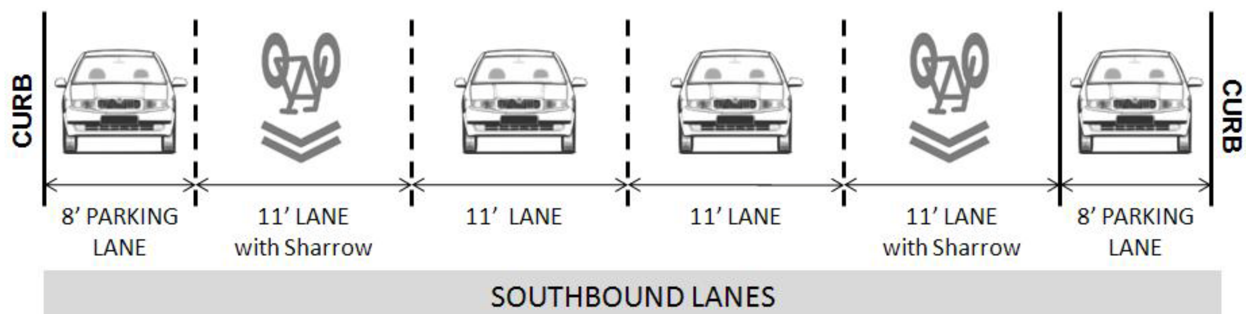

Figure 2. A cross-section of Guadalupe Street approaching the intersection with 12th Street

Data was collected by a traffic camera mounted at the intersection of Guadalupe Street and 12th Streets in downtown Austin. The camera was positioned to record southbound traffic as it approached 12th Street. One unique feature of the Guadalupe site is that on-street parking is provided along both sides of the facility, represented by the shaded area in Figure 3. During peak commuting hours (when data was collected) the parking spaces were rarely full, allowing bicyclists to bypass queues by riding in the empty parking spaces.

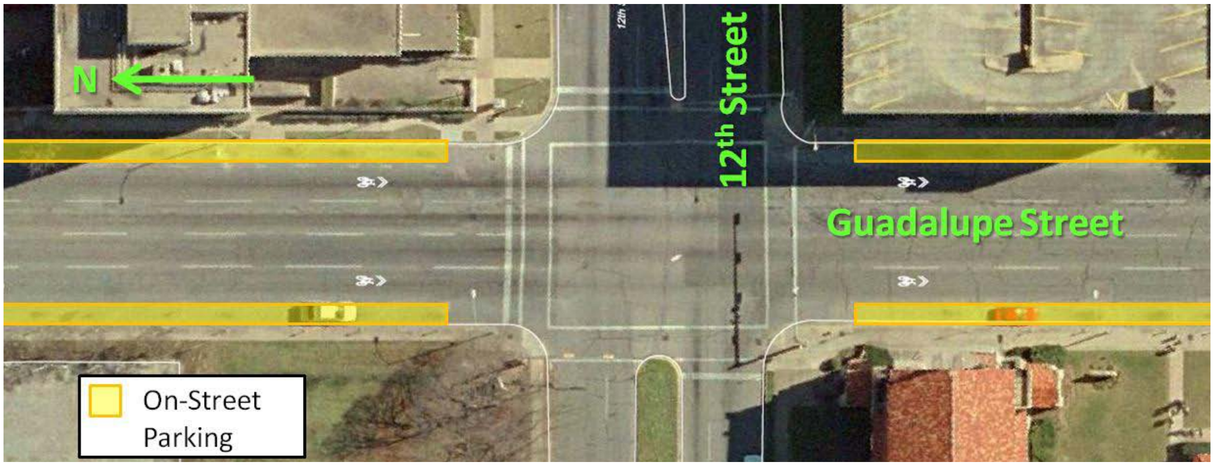

Figure 3. A map of the intersection of Guadalupe and 12th Street

Along E 51st Street between Airport Boulevard and IH-35

E 51st Street is a four-lane arterial that connects the suburban neighborhoods of north-central and north-east Austin. The facility has bicycle lanes west of Airport Boulevard and east of IH-35, but the lane width between Airport Boulevard and IH-35 is narrow, forcing bicyclists and motorists to share the road. In order to increase the bicycling appeal of this route, sharrows were placed in the rightmost lane along both the east- and westbound directions of this segment in the center of the lane. A cross-section of the site is shown in Figure 4.

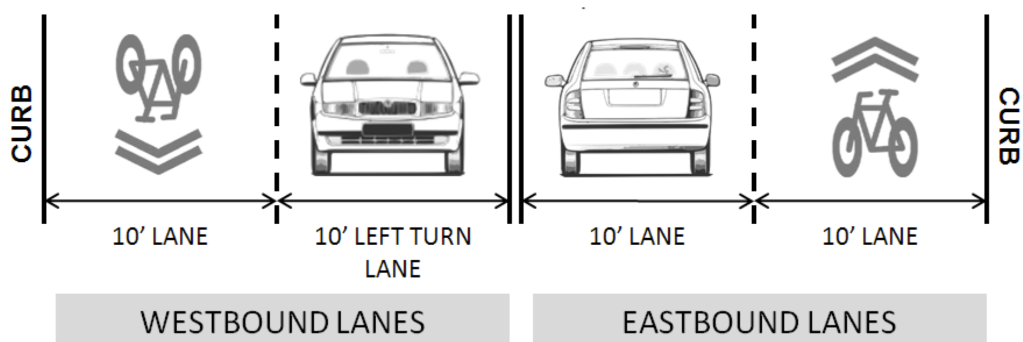

Figure 4. Cross-section of Westbound 51st Street approaching the intersection with Airport Boulevard

A traffic camera located at the intersection of Airport Street and E 51st Street captured traffic moving in both directions along the eastern leg of the E 51st Street and Airport Boulevard intersection. Traffic volumes were typically around 400 vehicles per hour in both the AM and PM peak periods and the speed limit is 30 mph. Bicyclists approaching the intersection (traveling west) were presented with different traffic conditions than bicyclists departing the intersection (traveling east). In order to account for these differences, each direction was considered separately. Figure 5 shows a sharrow installed at the study location on E 51st Street.

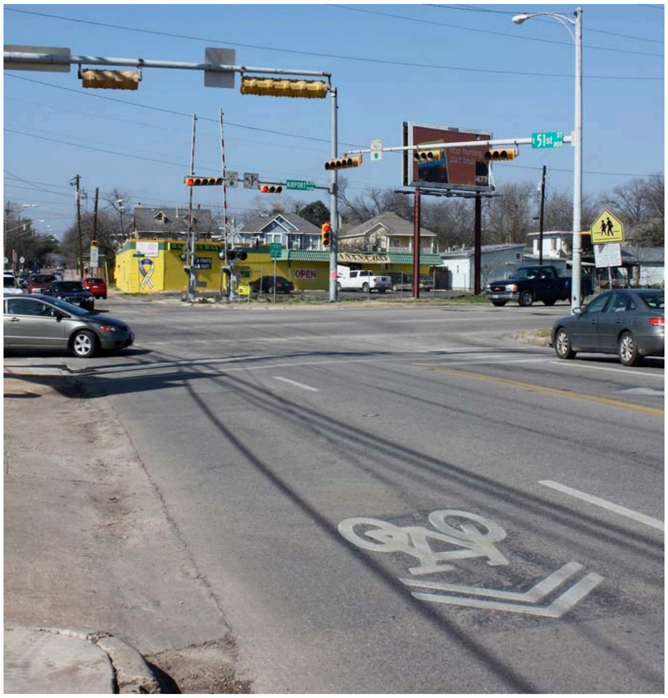

Figure 5. Shared Lane Marking installed on E 51st Street

Along Dean Keeton Street between San Jacinto Boulevard and Guadalupe Street

Dean Keeton Street is an east-west arterial that runs along the north side of The University of Texas at Austin campus. In Summer 2009, bicycle lanes were installed for the segment of Dean Keeton Street east of San Jacinto Boulevard as well as where space permitted on segments of Dean Keeton Street west of San Jacinto Boulevard. Where space did not permit the installation of bicycle lanes in accordance with City of Austin standards, sharrows were installed in August 2009. A cross-section of the roadway is shown in Figure 6. This paper compares the data collected after the installation of the bicycle lanes (but before the addition of the sharrows to the gaps) to the data collected after the installation of the sharrows.

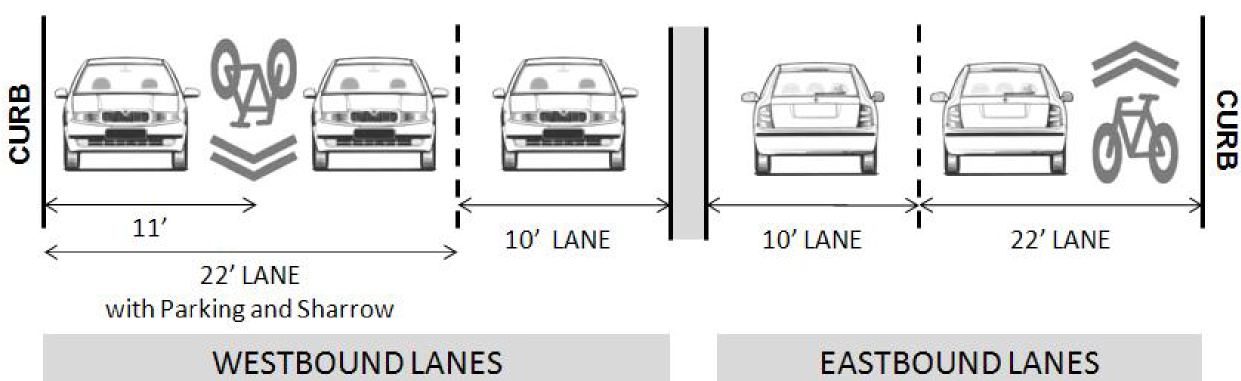

Figure 6. Cross-section of Westbound Dean Keeton Street departing the intersection with San Jacinto Boulevard

Data for this site was collected from a vantage point above the west leg of the intersection of Dean Keeton Street and San Jacinto Boulevard. Traffic volume along Dean Keeton Street was typically around 500 vehicles per hour and the speed limit is 35 mph. From this location, bicyclists were recorded traveling westbound just after departing the intersection. Sharrows were not installed in the center of the lane, but rather off to one side. In accordance with MUTCD standards, sharrows were centered 11 feet from the curb, leaving 11 feet between the sharrow's center and the next full lane. Figure 7 shows the studied segment of Dean Keeton Street near San Jacinto Boulevard.

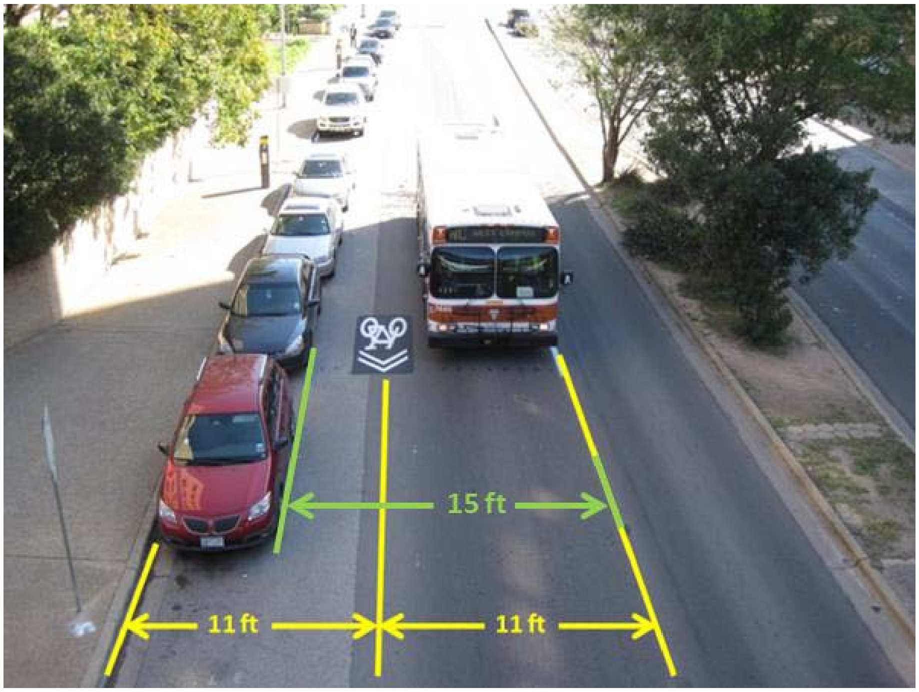

Figure 7. Shared Lane Marking position near the study site on Dean Keeton Street

Experimental Design and Research Methodology

In order to measure and evaluate bicyclist and motorist behavior, video footage of traffic movements at each site was collected. Video was recorded during the typical morning and afternoon peak periods for non-campus sites. Sites near campus were recorded during the morning peak period and from 2-5pm, when traffic leaving the university seemed to be highest. Video was played back on flat panel monitors for analysis and a transparency placed over the screen allowed measurements of bicyclist and motorist lateral position to be recorded. Measurements taken on Guadalupe Street had a resolution of one-tenth of a lane width (13.2 inches), E 51st Street had a resolution of one foot (12 inches), and Dean Keeton Street had a resolution of one-tenth of a lane width (18 inches).

The primary goal of this study was to determine what effect, if any, sharrows have on bicyclist and motorist safety. Therefore, before-sharrow and after-sharrow data for each site were compared to determine if safer conditions existed after the installation. For this study, safety was defined along the following lines. First, safe bicyclist behavior was defined by three factors: (1) riding in the lane position indicated by the sharrow, (2) not riding outside of the lane (on the sidewalk or in empty parking spaces), and (3) not riding alongside queues of stopped vehicles. Second, safe motorist behavior was defined by by three factors: (1) motorists give adequate space to bicyclists when passing, (2) motorists did not encroach on adjacent lanes when passing, and (3) motorists make complete lane changes when passing.

To evaluate safety as defined above, several elements of the environment, bicyclist behavior, and bicyclist-motorist interaction were recorded. Although no single measurement can comprehensively measure bicyclist and motorist safety, the improvement of several safety indicators can contribute to the conclusion that safety is indeed improved. Among the measurements taken were: traffic volume, position of motor vehicles and bicycles during passing and non-passing events, percent of motor vehicles that change lane to pass or make an incomplete passing maneuver, percent of bicyclists traveling with traffic (as opposed to against traffic or on sidewalks), and percent of bicyclists who bypassed a queue of stopped vehicles. Figure 8 illustrates how measurements of the bicyclist lateral position (BLP) and motorist (MLP) were recorded.

Figure 8. Method for taking BLP and MLP measurements using different measurement axes

Tests of statistical significance were conducted to determine if there were any notable differences between the before and after data. All proportions and means were compared using a two-sided test of equality, where the null hypothesis was that no change occurred and the alternative hypothesis that behavior changed. Educational information was intentionally not distributed to the public so that the device's impact could be measured without interference. However, Austin citizens were involved in the proposal's development. Bicyclists were solicited for their preferences for experimental locations, an opportunity for citizen comment was provided when the Austin City Council voted to fund this project, and a presentation of the proposal has been given to the City's Bicycle Advisory Committee where further comments from citizens were noted.

Terminology

The following terms are used throughout this paper to characterize the actions of bicyclists and motorists at the various sharrow sites.

- Bicyclist lateral position (BLP) – BLP is a measure of the bicyclist's position within the lane. Due to geometric differences, BLP was measured in a manner most consistent with each site's unique configuration. On 51st Street, BLP was measured as the lateral distance between the bicyclist's front wheel and the curb. On Guadalupe Street, BLP was measured as the lateral distance between the bicyclist's front wheel and the on-street parking space delineation marking. On Dean Keeton, no parking space delineation marking existed, so BLP was measured as the lateral distance between the bicyclist's front wheel and the parked motor vehicle's outer edge.
- Motorist Lateral Position (MLP) – MLP is defined as the distance between the motorist's curb side wheel and the appropriate measurement point—curb, delineation marking, or parked motor vehicle—as explained in the BLP definition.
- Stronger (or Weaker) Lateral Position – A strong lateral position is one that is far from the curb. A bicyclist riding in the middle of the lane is said to have a stronger lateral position than a bicyclist riding alongside the curb.
- Avoidance Maneuver – An avoidance maneuver was recorded whenever a bicyclist rode outside of the lane (e.g. rode on the sidewalk or in empty on-street parking spaces).
- Bypass the Queue –When a bicyclist was observed riding around a queue of stopped vehicles, the bicyclist was recorded as bypassing the queue.
- Passing Event (P) – A passing event was recorded when a motorist who previously shared the lane with a bicyclist pulled around the bicyclist. The measurements of BLP and MLP were taken simultaneously at the instant the front edge of the bicycle drew even with the front edge of the passing motorist.
    - Incomplete Passing Event - An incomplete passing event was recorded when the motorist passed a bicyclist without changing lanes.
- Non-passing Event (NP) - A non-passing event was recorded when a bicyclist rode past our camera and a passing event did not take place. This was usually because motorists were absent from the facility or because the motorists on the facility did not pass.
- Encroachment – Encroachment was recorded when a passing motorist occupied two lanes while passing.

Results

The following section describes the results of the study. Although many pieces of information were collected about bicyclist and motorist behavior, the measured lateral positions of bicyclists and motorists, as well as information about sidewalk riding proved to be the most revealing and are studied in detail below. Table 1 shows the number of observations gathered from each of the four study sites. Since little information was known about the frequency of bicyclist use on each site before the study began, more hours of video—and therefore more bicyclists—were recorded during the 'before sharrows' condition. Additional data on average number of bicyclist per hour organized by hour of the day and day of the week is included in Appendix A, which can be found at the end of this report.

Table 1. Non-passing and passing events at the four study sites

	Before Sharrows			After Sharrows		
	Non-Passing	Passing	**Total**	Non-Passing	Passing	**Total**
Guadalupe Street	260 (67%)	129 (33%)	**389**	203 (89%)	26 (11%)	**229**
Dean Keeton Street	152 (50%)	151 (50%)	**303**	85 (57%)	65 (43%)	**150**
E 51st Street Westbound	75 (84%)	14 (16%)	**89**	60 (92%)	5 (8%)	**65**
E 51st Street Eastbound	42 (55%)	34 (45%)	**76**	40 (41%)	57 (59%)	**97**

Southbound on Guadalupe Street at 12th Street

Figure 9 shows the distribution of BLP during mid-block travel on Guadalupe Street. Note that the center of the sharrow was placed 5.5 feet from the parking space delineation markings. After the sharrows were installed, the average BLP increased by 4.4 inches from 3.14 feet to 3.51 feet. More importantly, the mode [1]increased from 1.1 feet to 5.5 feet. Figure 6 shows that the percentage of bicyclists riding in the center of the lane (defined as BLP between 4.4 and 6.6 feet) increased significantly from 31% to 42% after the installation of the sharrows. Overall, the lateral position data suggests that the sharrow encouraged bicyclists to ride with a stronger lateral position and more predictably than before. This trend is also evident in the substantial decrease of bicyclists observed riding further than 7 feet from the lane edge. A significant change in BLP during passing events was not observed at this site.

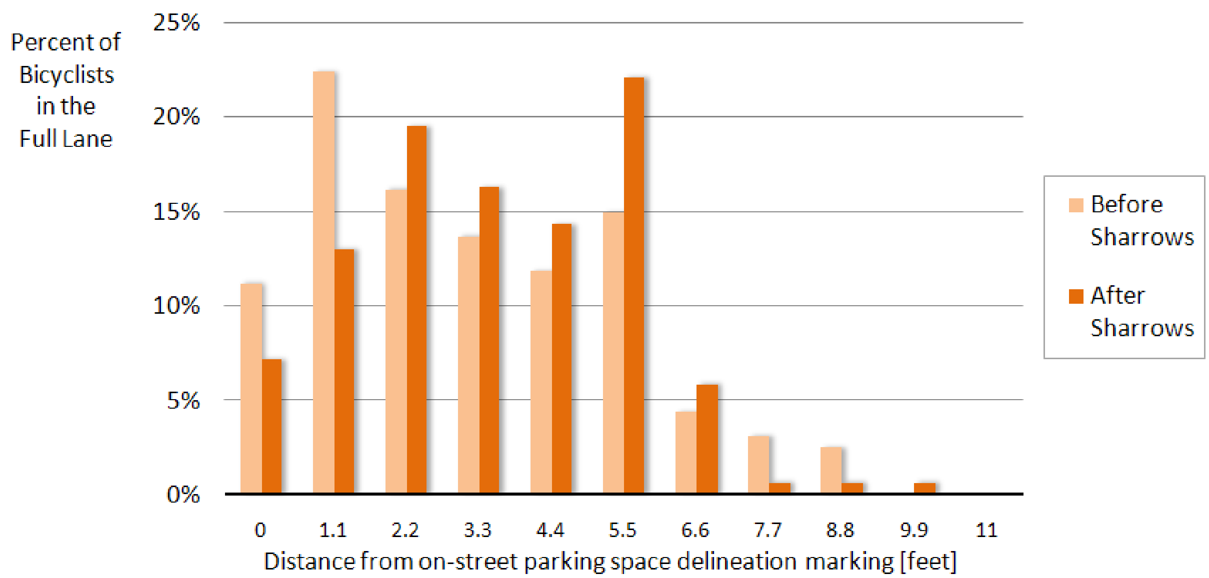

Figure 9. Distribution of bicyclist lateral position along Guadalupe Street during non-passing events

The histogram in Figure 10 shows four statistically significant results that suggest sharrows have a substantial influence on both motorist and bicyclist behavior. First, bicyclists were less likely to make an avoidance maneuver after the implementation of the sharrow and motorists were more likely to change lanes while passing after the implementation of the sharrow. Another interesting comparison shows that while bicyclists were less likely to make an avoidance maneuver, they were more likely to bypass a queue of stopped vehicles after the sharrows were in place. This may suggest that the sharrow encouraged bicyclists to assert themselves more when sharing the roadway with motorists.

[1] *Mode* is a statistical term that describes the value that occurs most frequently in a set of data. In this case, the *modal* lateral position is the most common position that bicyclists take within the lane.

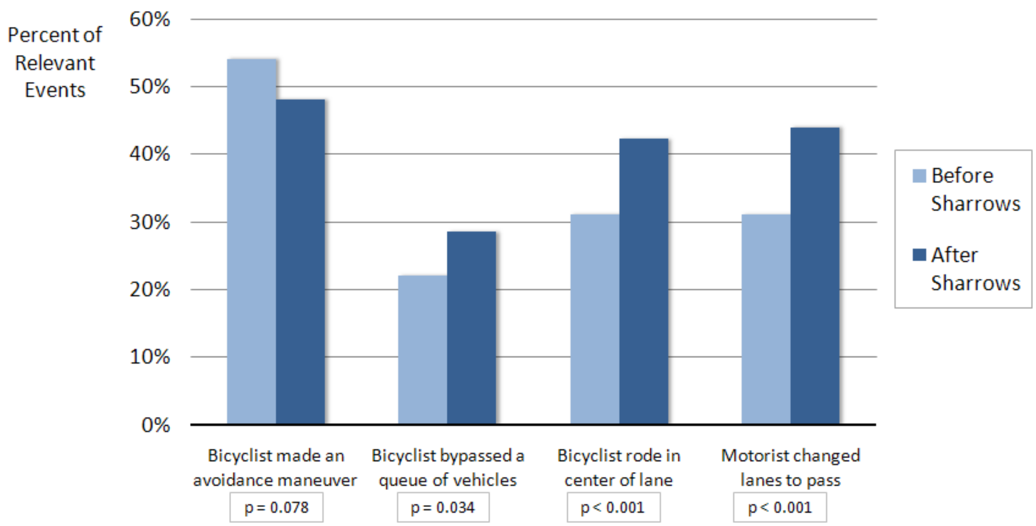

Figure 10. Notable comparisons on Guadalupe Street

Westbound Along E 51st Street Approaching Airport Boulevard

In general, the improvements in safety observed on 51st Street are similar to those seen on Guadalupe Street. As Figure 11 illustrates, bicyclists approaching the intersection of E 51st Street and Airport Boulevard were observed riding between one and ten feet from the curb face at mid-block. After the sharrows were installed, bicyclists tended to take a stronger position in the lane as evidenced by the increase in average BLP by 8 inches from 4.0 feet to 4.75 feet. As was the case on Guadalupe Street, the most significant result may be the increase in mode from 3 feet to 5 feet. Figure 12 shows that the proportion of on-street bicyclists who rode in the center of the lane (defined as an BLP between 4 and 6 feet) increased from 44% to 54%. The results for BLP or MLP during passing events are not presented because so few passing events were recorded in this direction—see Table 1. Since bicyclists approaching the intersection with Airport Boulevard often faced a queue of vehicles at low speeds, there were fewer opportunities for a passing event to occur.

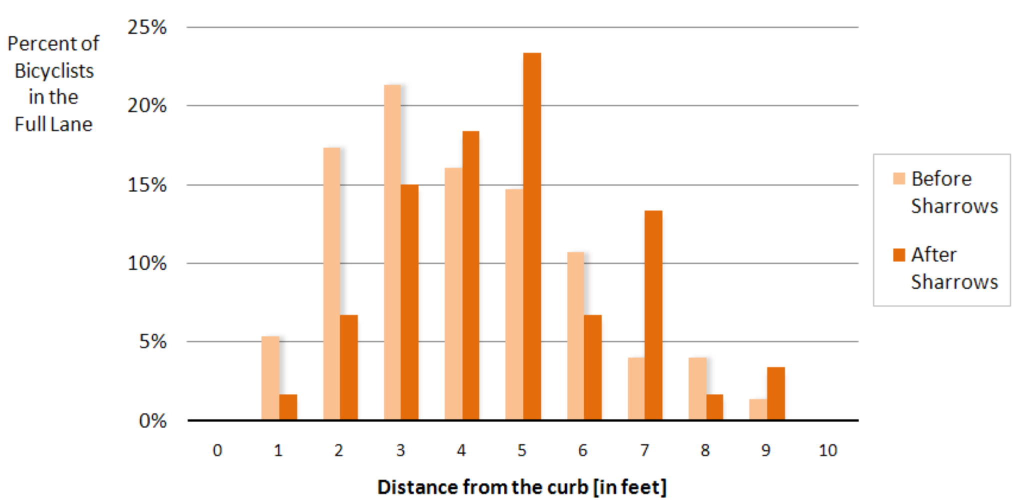

Figure 11. Distribution of bicyclist lateral position on 51st Street approaching Airport Boulevard during non-passing events

Figure 12 compares notable bicyclist behaviors before and after the implementation of the sharrows. Both the percentage of bicyclists who bypassed a queue or who made an avoidance maneuver remained unchanged after the installation of the sharrows. This may suggest that bicyclists on E 51st Street choose to ride on the sidewalk or ride around a queue of stopped vehicles for convenience, not for perceived lack of safety. The presence of the Shared Lane Marking led to a significant decrease—from 12% to 4%--of bicyclists riding against traffic on the sidewalk. As mentioned previously, the proportion of bicyclists riding in the center of the lane did increase substantially; indicating sharrows can be effective at encouraging bicyclists to take a strong position in the full lane.

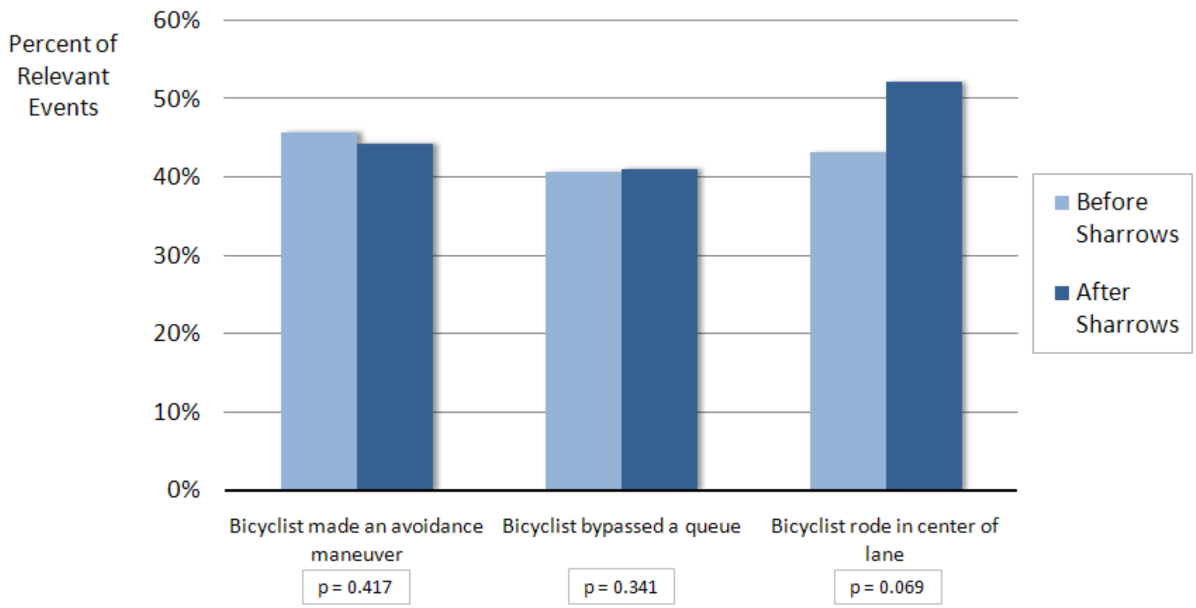

Figure 12. Notable comparisons on E 51st Street westbound approaching Airport Boulevard

Eastbound Along E 51st Street Departing Airport Boulevard

Bicyclists departing the intersection of E 51st Street and Airport Boulevard were frequently passed by motorists. Relative to the BLP measured on other sites, bicyclists on E 51st Street took a very weak position in the lane during passing events. Figure 13 compares the BLP before and after the implementation of the sharrows. After the sharrow installation, the mode increased from 1 foot to 2 feet and the percent of bicyclists riding in the middle of the lane increased significantly. This shift suggests that when a sharrow is present, bicyclists are willing to take a stronger position in the lane, even when being passed.

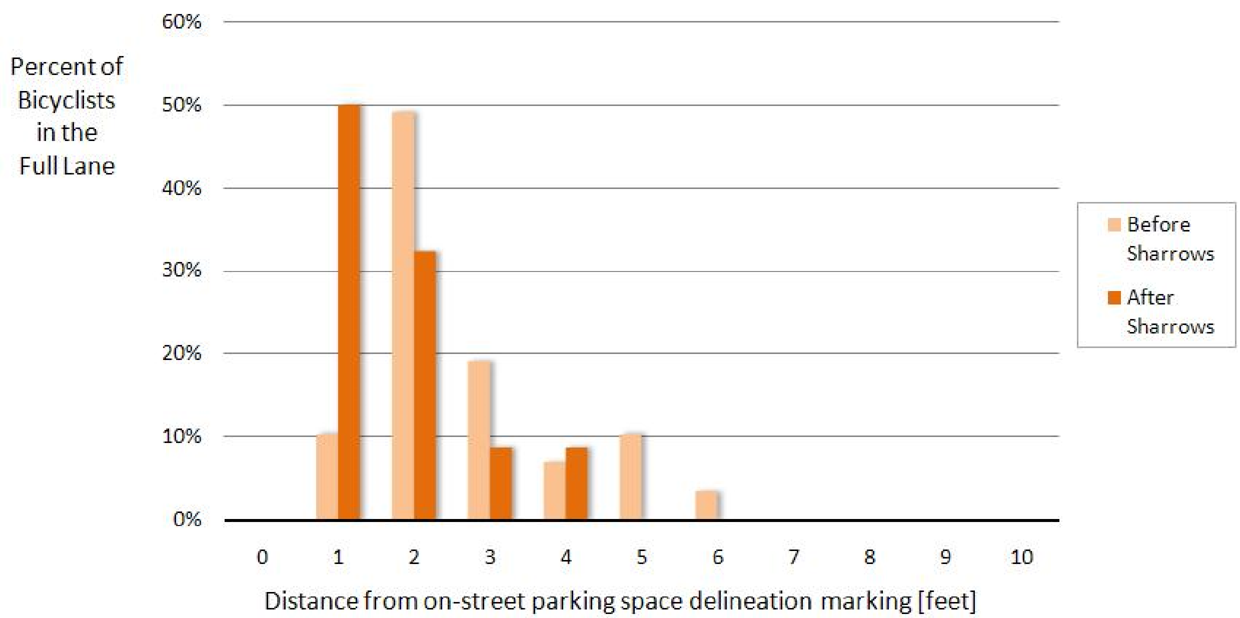

Figure 13. Distribution of bicyclist lateral position on E 51st Street departing Airport Boulevard during passing events

Avoidance maneuvers were relatively rare at this site and after the installation of the Shared Lane Markings the proportion of avoiding bicyclists decreased further as illustrated in Figure 14. The percentage of bicyclists occupying the center of the lane (defined as BLP between 4 feet and 6 feet) during non-passing events increased significantly. This change, along with the substantial increase in bicyclists riding in the center of the lane during passing events suggests that the sharrow markings encouraged bicyclists to properly share the road with vehicles, even when faced with a high number of passing events. Although not shown in Figure 14, the presence of the sharrow marking led to a significant decrease—from 12% to 4%—of bicyclists riding against traffic on the sidewalk along E 51st Street.

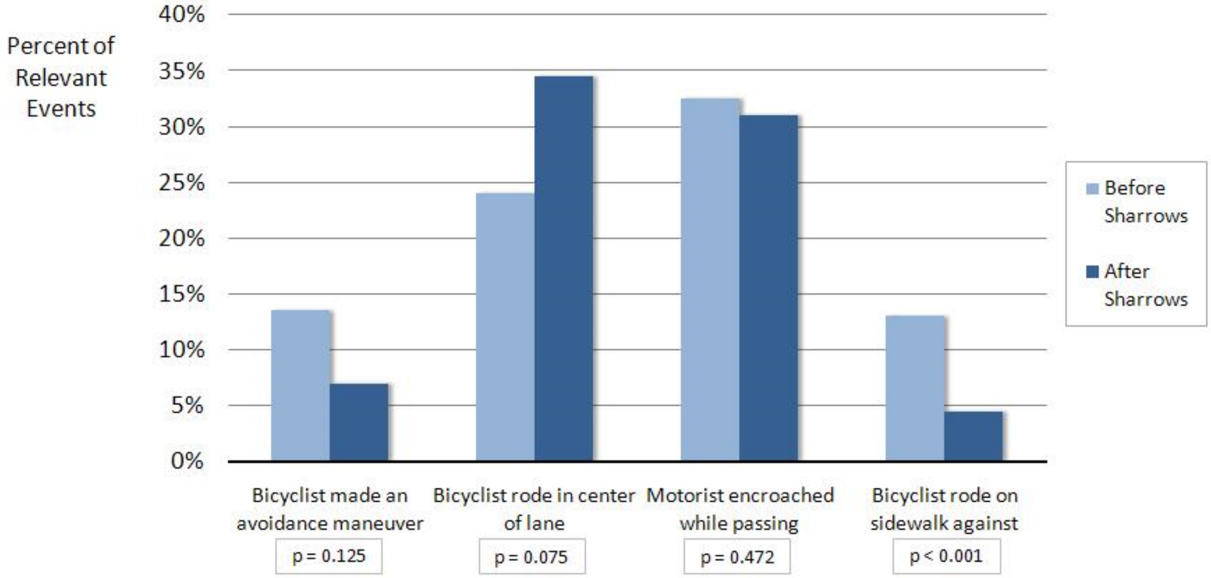

Figure 14. Notable comparisons on E 51st Street Eastbound departing Airport Blvd

Westbound on Dean Keeton Street at San Jacinto Boulevard

As mentioned in site description, the unique site geometry and the fact that bicyclists departing an intersection are frequently passed by motorists made bicyclist safety during passing events a key concern for this site. Figure 15 and Figure 16 compare bicyclist lateral position before and after the sharrow installation for both passing and non-passing events, respectively. The most significant trend suggests that after the sharrow installation, bicyclists tend to behave more predictably. In the before conditions, bicyclist position during passing events varied between 1.5 feet and 4.5 feet, while after the installation, nearly 70% of bicyclists rode at 3 feet. A similar but less pronounced trend can be observed for non-passing events. Although the decrease in standard deviation of BLP during passing events is noticeable, tests show that the change is not statistically significant (p=0.363). Together, this information suggests that the sharrow can substantially influence the consistency of bicyclist lateral position.

Figure 15. Distribution of bicyclist lateral position on Dean Keeton Street during non-passing events

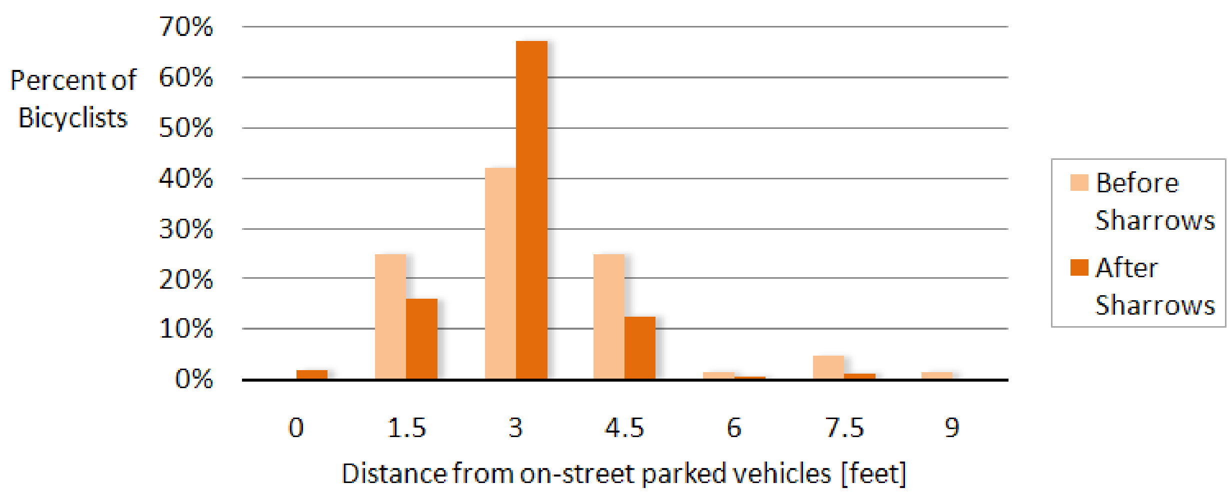

Figure 16. Distribution of bicyclist lateral position on Dean Keeton Street during passing events

Note: Although BLP could be measured up to 15 feet from the edge of the on-street parked vehicles, no bicyclists were observed riding at a position greater than 9 feet from the edge of on-street parked vehicles.

As illustrated in Figure 17, instances of bicyclist avoidance decreased substantially after the sharrows were installed and the proportion of passing motorists who encroached on the adjacent lane decreased as well. This change, coupled with the increased predictability of bicyclist position during passing events, suggests that motorists feel more comfortable passing bicyclists when the sharrow is present and are therefore less likely to encroach on the adjacent lane when passing. (Note that the dimensions of Dean Keeton Street do not require motorists to change lanes to pass.) Taken together, these results suggest that sharrows can be effective as a tool to connect areas where bicycle lanes are not continuous.

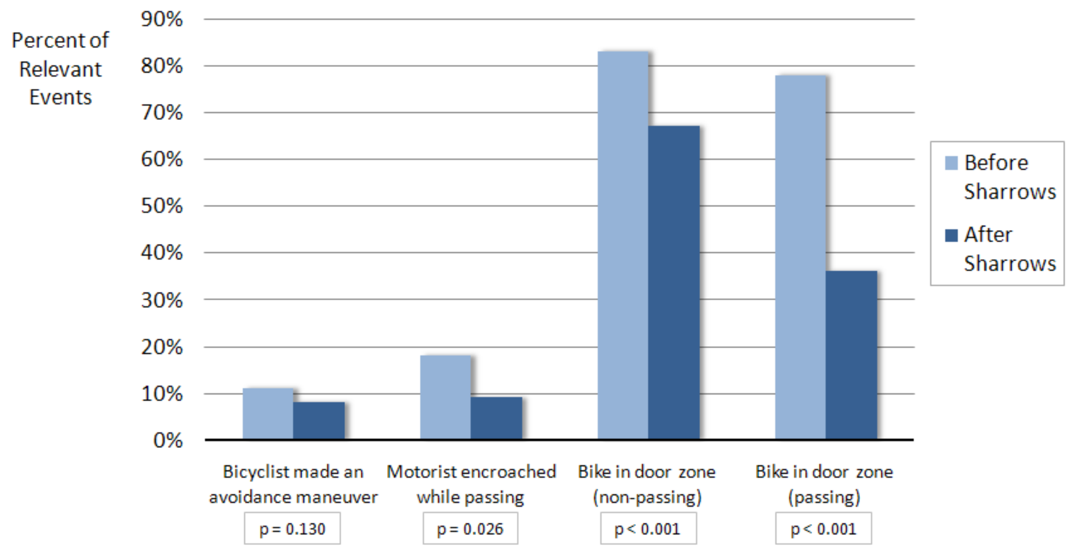

Figure 17. Notable comparisons on Dean Keeton Street

Conclusions and Recommendations

The collective observations in this study strongly suggest that Shared Lane Markings can improve the safety of both bicyclists and motorists on multi-lane facilities when used as either a standalone device or as a tool to guide bicyclists between facilities with bike lanes. This study observed that after the installation of the Shared Lane Markings, bicyclists generally rode further from the curb and closer toward the center of the lane. At several sites, the Shared Lane Marking was effective at reducing unsafe bicyclist behavior (such as riding on the sidewalk or bypassing a queue of stopped vehicles). Additionally, the installation of the Shared Lane Markings resulted in improved motorist behavior when passing a bicyclist—motorists were more likely to change lanes to pass and were less likely to encroach on the adjacent lane when passing.

Given these results, we recommend that Shared Lane Markings be employed on multi-lane facilities where the facility cannot be reasonably adjusted to accommodate a bike lane. This study found that Shared Lane Markings improved bicyclist and motorist behavior on sites with posted speed limits of 30 mph and with peak traffic volumes between 400 and 1650 vehicles per hour. Shared Lane Markings can be effective on such facilities as a stand-alone device (as evidenced by the Guadalupe site) or as a means to connect two bike lane facilities (as evidenced by the 51st Street and Dean Keeton sites).

As observed on Dean Keeton Street, Shared Lane Markings can be particularly effective at removing bicyclists from the door zone of on-street parked vehicles. The Dean Keeton Street site saw the average bicyclist lateral position increase only marginally, however, this small average increase in bicyclist lateral position resulted in a significant decrease in the proportion of bicyclists who were in the door zone during both passing and non-passing events.

We further recommend that Shared Lane Markings be placed in the center of the lane unless it is possible for bicyclists and motorists to share the lane side-by-side safely (e.g. the bicyclist is not forced to ride in the door zone of on-street parked vehicles and the bicyclist can be passed with a clear distance of at least three feet).

Further research is needed to determine if the addition of Shared Lane Markings to a facility increases bicycle use of that facility. Also, this study did not attempt to determine the effectiveness of Shared Lane Markings along single lane facilities; therefore, we cannot recommend their use on single lane facilities.

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Appendix A: Bicycle Count Data

The following figures illustrate the level of bicycle traffic that E 51st Street, Guadalupe Street, and Dean Keeton Street received before and during the course of this study. Figures A1, A2, and A3 show the number of bicyclists recorded at each site for each hour of the day, expressed in military time (where 15 represents 1500 hours, or 3:00pm). At both Airport Boulevard and Guadalupe Street the number of bicyclists per hour was generally higher in the afternoon peak. Also, the number of bicyclists per hour at E 51st Street, and Guadalupe Street increased with time during the morning peak hours and decreased with time during the afternoon peak hours. These trends are similar to ridership trends observed on Lamar Boulevard, which was observed during a “Bicycles May Use Full Lane” sign study. There is a high, but variable number of bicycles per hour along Dean Keeton Street, so few conclusions can be drawn about bicyclist patterns at this location. The variability in bicyclist volume is most likely due to site’s close proximity to the University of Texas. The before data was collected while summer classes were in session at the University, while the after data was collected during the fall semester. The increase in bicycle volume on Dean Keeton street would be due in large part to the increase in student population during the fall semester.

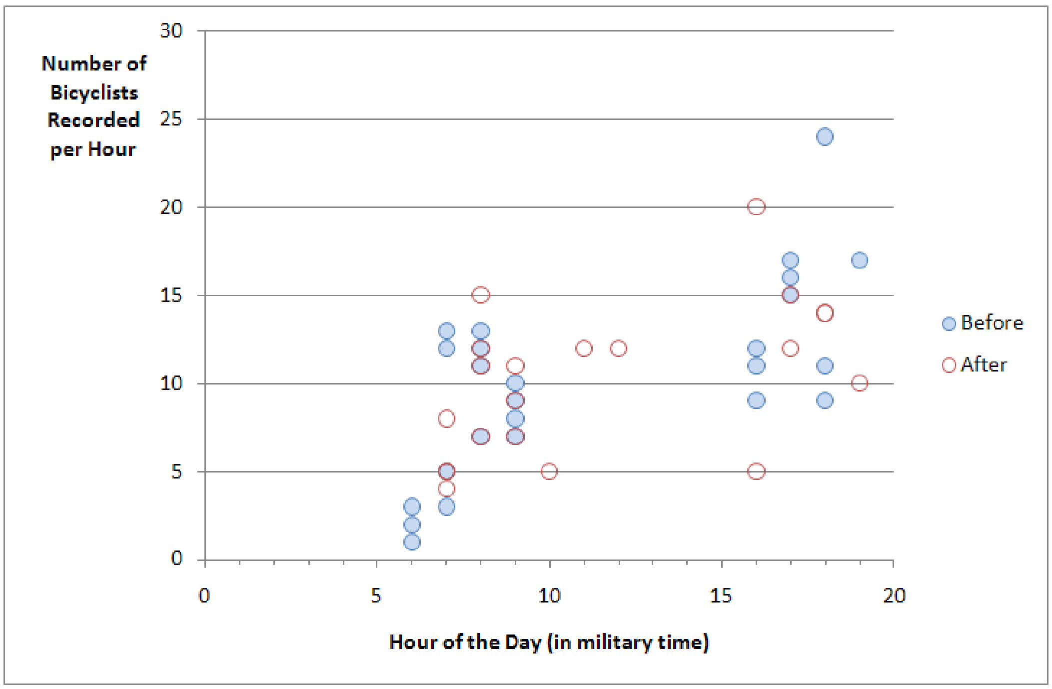

Figure A1: Number of bicycles recorded each hour of the day on E 51st Street
Note: These data points include bicyclists traveling in both directions along 51st Street

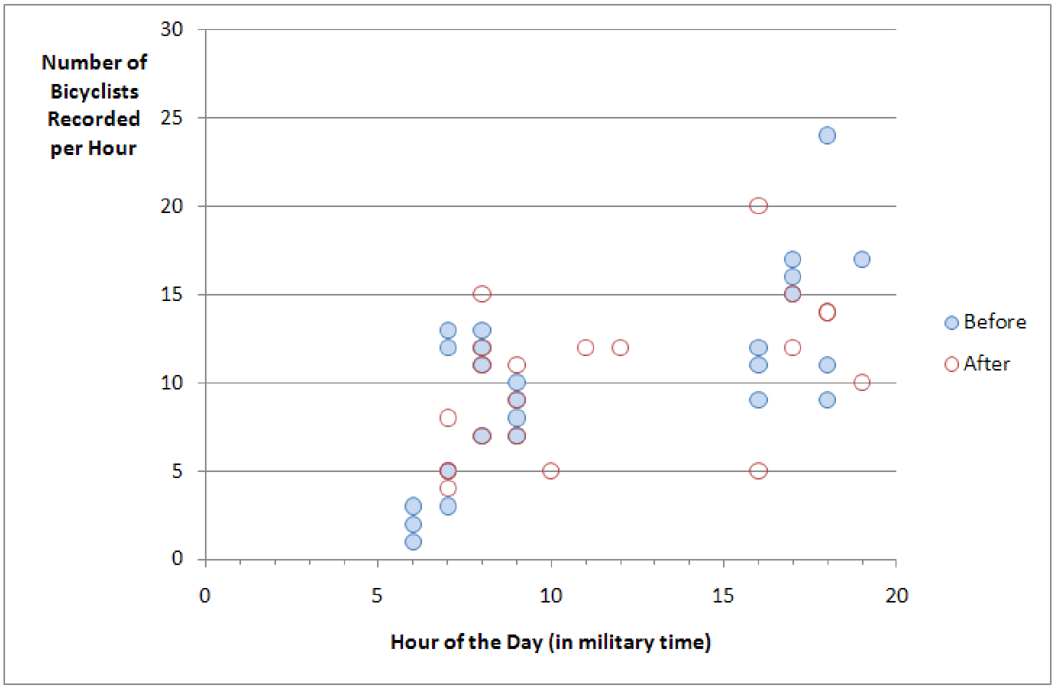

Figure A2: Number of bicycles recorded each hour of the day on Guadalupe Street

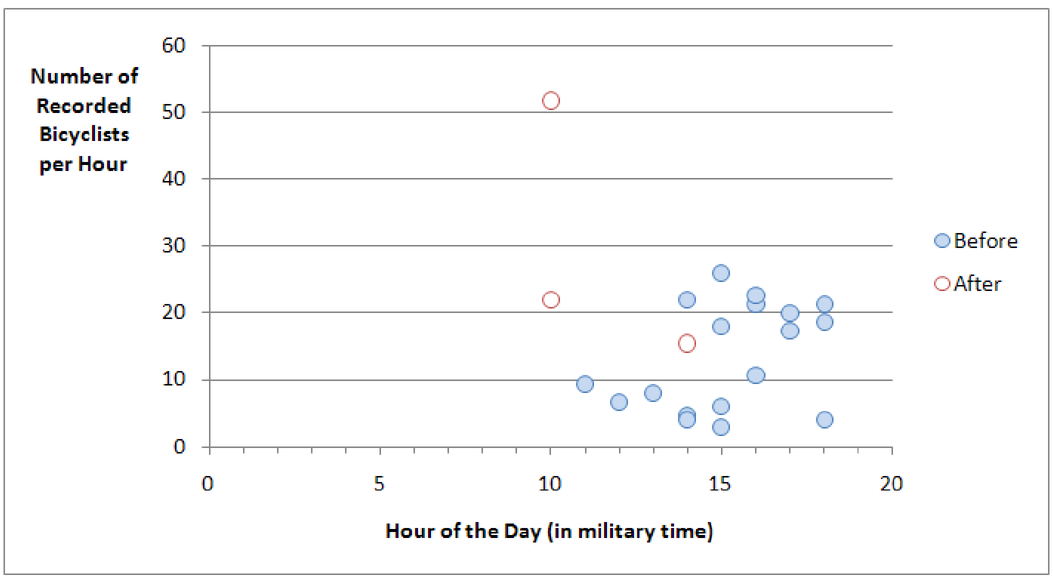

Figure A3: Number of bicycles recorded each hour of the day on Dean Keeton Street

Figures A4, A5, and A6 show the number of bicyclists recorded per hour for each day of the week along E 51st Street, Guadalupe Street, and Dean Keeton Street, respectively. E 51st Street, experienced a higher hourly volume of bicyclists (9.9 bicyclists per hour) than Guadalupe Street (8.0 bicyclists per hour), but both volumes were relatively constant for each weekday. This trend contributes to the hypothesis that E 51st Street and Guadalupe Street are primarily used as commuter routes. The average volume along Dean Keeton was 16.1 bicyclists per hour and was relatively constant for each day of the week as well. This indicates that despite bicyclist volume varying each hour of a day, Dean Keeton Street experiences consistently high ridership each day of the week.

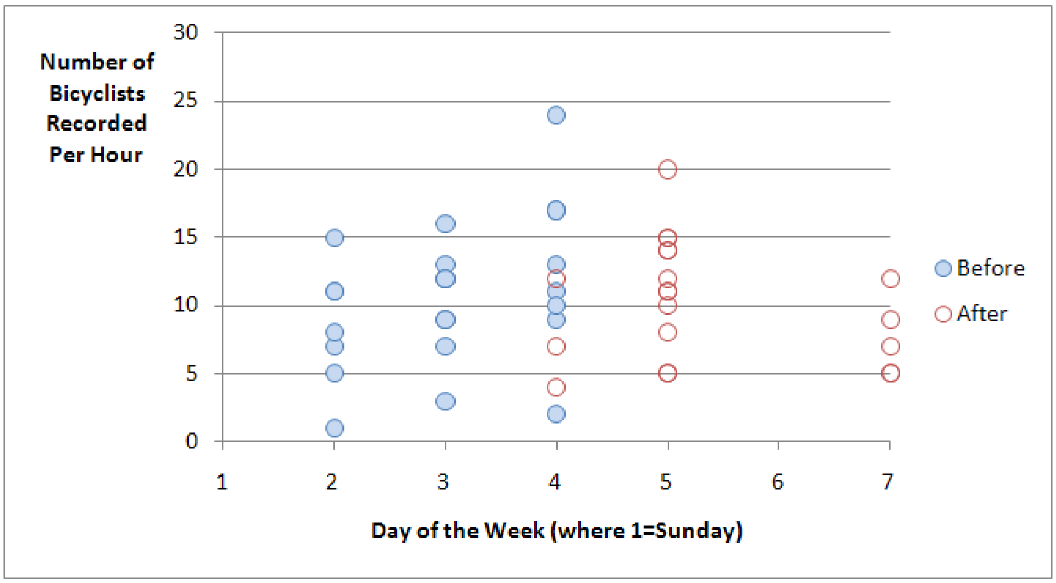

Figure A4: Number of bicycles recorded each day of the week on E 51st Street
Note: These data points include bicyclists traveling in both directions along 51st Street

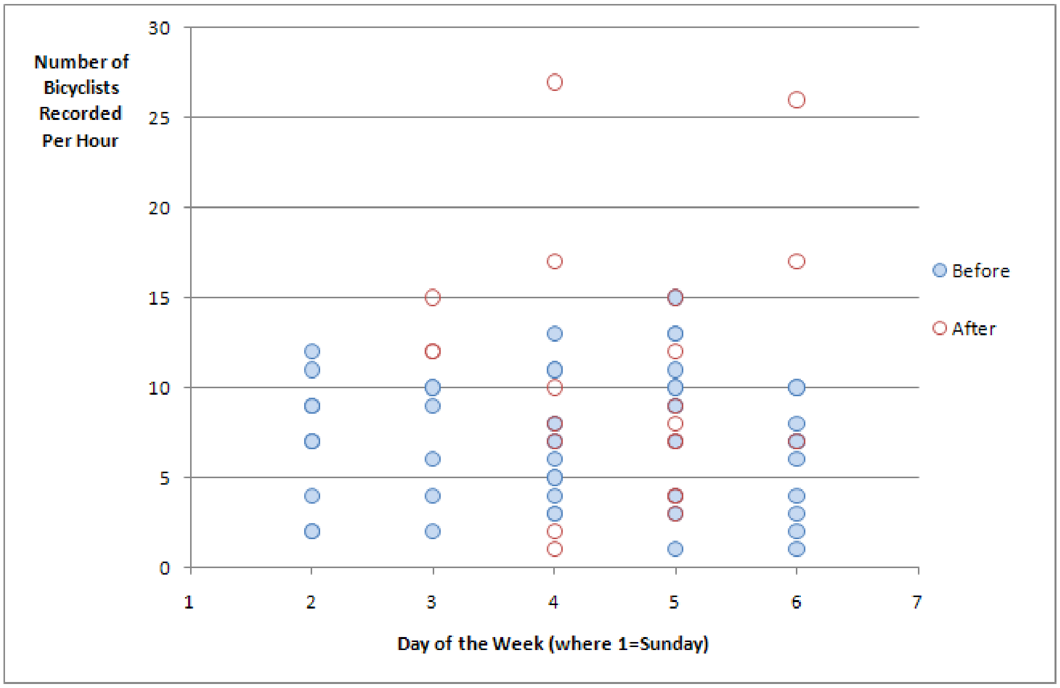

Figure A5: Number of bicycles recorded each day of the week on Guadalupe Street

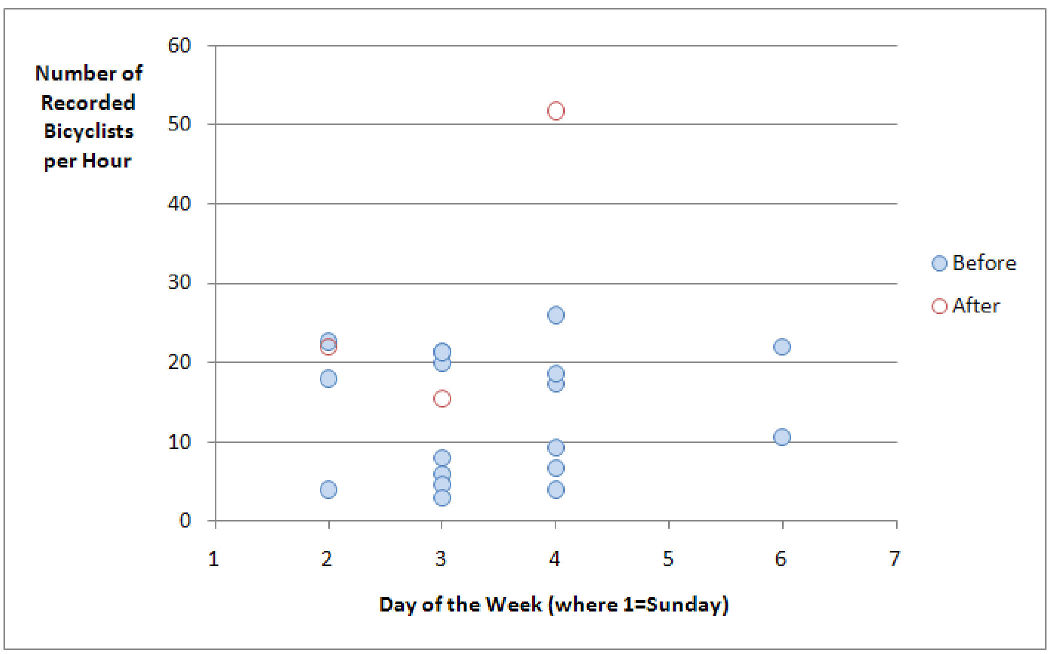

Figure A6: Number of bicycles recorded each day of the week on Dean Keeton Street

Appendix B: Thermoplastic Cost, Maintenance, and Upkeep

The colored thermoplastic, sharrows, and other thermoplastic forms were purchased from Flint Trading Inc (Thomasville, NC). Costs for these materials are provided in Table XX.

Table B1. Cost of thermoplastic units used in the studies

Item	Cost	Unit
Colored Thermoplastic	$4.46	SF
Sharrows	$126.30	EA
"WAIT HERE" Legend	$267.66	EA
Bicycle Symbol	$98.21	EA

Per manufacturer guidelines, the installation of the colored thermoplastic first required the application of an oil-based coating to the asphalt. The optimal installation of this initial layer would be an application to asphalt free of debris and sediment. The oil layer needed to dry (WC) before the colored thermoplastic could be laid out. Otherwise, the heat applied to the thermoplastic would cause the oil to burn through the material.

An installation error of the colored thermoplastic on Dean Keaton at the IH-35 exit ramp led to its quick deterioration. While waiting for the oil layer to dry one of the crew members spilled a large amount of water onto the oil. This water eventually led to inadequate bonding between the pavement and the thermoplastic, which resulted in the thermoplastic breaking up (illustrated in Figure B1).

Figure B1. Deteriorating thermoplastic on one of the I-35 exit ramps (breaking up in sheets)

The quality of pavement was a contributing factor to the quick deterioration of the colored thermoplastic, illustrated in Figure XX. In particular, the pavement on Speedway at 38th Street is cracked and uneven from the high volume of bus traffic. (The street is scheduled for reconstruction in the next few years.) Clearing debris from the deep cracks of the application surface was nearly impossible; applying the oil-layer to these same cracks and the other surface flaws was also troublesome. The resultant colored thermoplastic was only tenuously bonded to the street surface at best.

Figure B2. Poor quality of road lead to the deterioration of the thermoplastic bike boxes on Speedway Boulevard

Additionally, the colored thermoplastic on Speedway was discolored very quickly (see Figure B2). This discoloration is likely due to the heavy bus traffic on Speedway, where there is a peak hourly volume of over 15 buses/hour. This discoloration may have been compounded by the buses, wider than personal cars, driving in the colored lane. Another concern with the thermoplastic is shown in Figure B7. It is unclear whether the uneven application of thermoplastic shown in the photograph is the result of a misapplication, the rough nature of the street surface, or a deterioration problem.

Figure B3. Poor quality of road lead to the deterioration of the thermoplastic bike boxes on Speedway Boulevard

Installing colored thermoplastic on new pavement would be the optimal situation. In the future, the City of Austin will most likely be applying a fresh asphalt surface (seal coat, microsurface, or overlay) before the installation of any proposed colored thermoplastic. A fresh street surface will provide a surface free of cracks and other defects, which could lead to erroneous installation and quick deterioration. These properties also lessen the importance of the oil layer in creating a bond between the pavement and thermoplastic.

All sharrows were installed on top of a painted black box in order to provide visual contrast. Additionally, all sharrows were installed in the outside travel lanes. The sharrows on Guadalupe, Lavaca, and 51st Sts were installed in the center of the outside travel lanes as described by Figure B4. Each sharrow was individually placed in order to keep the sharrow out of the typical wheel paths and to avoid driveways where entering and exiting vehicles would have more variable wheel paths. By placing the sharrows outside of wheel paths the integrity of the thermoplastic was maintained.

Figure B4. Central placement of sharrow resulted in thriving thermoplastic five months after installation.

The east-bound sharrows on Dean Keeton St were installed in the center of the outside travel lanes (see Figure B5) in the same manner as the sharrows on Guadalupe, Lavaca, and 51st Sts. Like these other streets, centralizing the east-bound Dean Keeton sharrows helped to preserve the thermoplastic. Another reason these sharrows were installed in the center of the travel lane was to keep them out of the path of buses. Dean Keeton St has an extremely high volume of bus traffic (peak hourly volume of 40 buses/hour) and there a number of bus stops requiring buses to enter and exit the outer travel lane as shown in Figure B5. Finally east-bound bicyclists are also able to reach faster speeds because of the downhill allowing bicyclists and cars to travel at similar speeds.

Figure B5. Central placement of sharrows on east-bound, downhill Dean Keeton St.

The west-bound sharrows on Dean Keeton differed from the other locations as these sharrows were aligned closer to the curb (see Figure B6). These sharrows were aligned closer to the curb for the following reasons: the outside travel lane on west-bound Dean Keeton was very large, there were no bus stops, the sharrows were only utilized to provide a bicycle facility to link two bicycle lanes, and west-bound bicyclists slow down to travel uphill.

Figure B6. Curb-justified placement of sharrows on west-bound, uphill Dean Keeton St.

Figure B7. Thermoplastic thinning on the colored lane on San Jacinto Bouleveard